NON-PARABOLIC MARCHING ALGORITHM FOR SOUND FIELD CALCULATIONS IN THE INHOMOGENEOUS OCEAN WAVEGUIDE

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Long-range propagation

LONG-TERM GOALS

The long-term purpose is to develop a new effective algorithm for sound field calculations in the inhomogeneous ocean waveguide. This algorithm will not involve parabolic approximation and can be considered as principally exact (at least for 2-D inhomogeneities of the sound speed field). Thus, it can be used in cases when the phase of the acoustic field should be calculated
accurately enough. It will be able to calculate not only acoustic field but the entries of scattering matrix for the modes of the ocean waveguide as well. The case of uneven fluid bottom with losses will be also considered. Thus, the algorithm will be able to provide exact solutions of the wave equation with two-dimensional inhomogeneities both for shallow- and deep-water situations.

SCIENTIFIC OBJECTIVES

To develop an algorithm effectively calculating Jost solutions (JS, see below) for the inhomogeneous waveguide in the deep water case without attenuation. To express the Green function of the wave equation and scattering matrix (S-matrix) for the ocean waveguide in terms of JS. Generalize the algorithm to the case of uneven bottom with losses (shallow water case). To incorporate into the algorithm calculation of travel times of different modes. To develop appropriate code for the acoustic field and S-matrix calculations and to check it with the help of suitable benchmark problems.

APPROACH

First, the solution of wave equation is expressed in terms of so called Jost solutions. The latter are specific solutions of the 2-D wave equation representing a generalization of normal modes for the case of inhomogeneous waveguide. JS can be calculated by "marching" which in contrast to PE methods starts from large distances and migrates towards the source. The crucial point of the approach is the way of recalculating the field at each step of backward "marching". In contrast to Evans's coupled-mode method appropriate vertical slices of the waveguide are not assumed to be horizontally homogeneous, and relatively weak mode interaction within each slice is taken into account in a perturbative manner. This allows one to increase the value of horizontal step

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significantly. Energy conservation and reciprocity relation provide convenient means of checking the accuracy of calculation and choice of the step value.

WORK COMPLETED

The JS for the case of ocean waveguide were introduced, and the expression for the field and S-matrix for normal modes is expressed in terms of JS. The reciprocity relation and unitarity condition are formulated in terms of S-matrix. In particular, the resulting expression for the acoustic field is reciprocal. The method of recalculating of the field from a vertical cross-section to the following one is developed. Appropriate code for deep water case was successfully checked with the help of benchmark problem. During 1997 most of the efforts were made towards generalization of the algorithm to the case of penetrable lossy fluid bottom. Appropriate theory was developed and the expression for the scattering matrix in this case was obtained. This task is much more difficult computationally, as it is related to calculation of complex spectrum of acoustic modes at each step. Newton's iterations based on the previous step are uneffective in the vicinity of critical depths, and some modifications to the mode calculations were evoked. Appropriate code was developed and numerical simulations started.

RESULTS

It is shown, that for typical deep-water situations the value of horizontal step (which is chosen automatically) varies from a few kilometers (for slow-varying "adiabatic" parts of the waveguide) up to a few hundred meters (for extremely fast-varying parts of the type of "frontal" zones). Effectiveness of the approach (in terms of the number of CPU operations) as compared to Evans's couple mode method was estimated. It was shown, that for typical mesoscale inhomogeneities this approach appears to be more effective by a factor of few hundreds. The code seems to be much faster as compared to COUPLE and IFDPE codes. The objective criterium for numerical estimation of the accuracy of different methods based on comparison of S-matrixes is also suggested. The shallow-water case due to sharp discontinuities of density and sound speed requires for accurate treatment relatively large number of modes.

IMPACT/APPLICATIONS

Developed algorithm and code can be used for numerical simulations of the sound propagation in the inhomogeneous ocean waveguide. This algorithm is exact, and can be especially useful when precise values of complex acoustic field is required. It is very effective numerically and does not require extensive computational resources (can be successfully run on PC).

RELATED PROJECTS

The developed non-parabolic algorithm was used for numerical simulation for the project "A New Scheme for Acoustical Tomography of the Ocean".

REFERENCES

A.G. Voronovich (1996): "Non-parabolic marching algorithm for sound field calculation in the ocean waveguide," J. Computational Acoustics, v.4, No. 4, 399-423.